

Contribution to NSAC Long-Range Plan.

The Gamma-Ray Energy Tracking Array, GRETA.

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Statement on GRETA:

The time is right to aggressively pursue the next step of development and implementation of the gamma ray energy tracking array (GRETA). Currently, there is a strong need for this powerful array due to a broad range of physics opportunities with potential for new discoveries. Within a decade, RIA will provide completely new possibilities in the studies of nuclear structure, nuclear astrophysics and fundamental symmetries. GRETA is the only detector which can satisfy the requirements of experiments using low energy stable beams, low energy radioactive beams from the ISOL method, and high-energy radioactive beams from fragmentation. The feasibility of GRETA has been demonstrated through recent development work in the following key areas: segmented detector performance, position determination, signal decomposition, and gamma-ray interaction tracking. The construction of GRETA will maintain the US leadership in gamma-ray detection and ensure the long-term success of the low energy nuclear physics program.

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I) INTRODUCTION

Advances in nuclear physics depend heavily on new instrumentation and accelerators. The acceleration of heavy ions to energies high enough to initiate fusion reactions has allowed nuclear studies to advance beyond the stable nuclei, and opened up the entire proton-rich side of the valley of stability. High angular momentum and high temperature nuclear physics in this region have been the center of nuclear structure research for more than three decades. Such studies have been rich with discoveries. The reaction of heavy ions is complicated, producing a wide variety of states. It has taken many years to harness the potential of these reactions and exploit their possibilities. Gamma-ray detectors have been an essential element in exploiting the potential of these heavy-ion fusion reactions. A series of spectrometers have been developed, culminating in Gammasphere, allowing us to extend gamma-ray studies to the highest spins, the proton dripline and into the heaviest nuclei, as well as to address some questions in fundamental interactions and astrophysics.

Now, accelerated exotic beams are generating new experimental challenges. Many opportunities for physics are on the horizon, especially in neutron-rich nuclei. Some of these are discussed in the next section. Again, gamma-ray studies will play a major role. However, technical innovation is needed to exploit these opportunities. The challenges are diverse, including the need for very high efficiency (when exotic beam intensities are low), accurate position resolution (for ions moving at relativistic velocities), good polarization sensitivity, and high efficiency for high-energy gamma rays. This diversity will require a modular and flexible solution, as many experiments will involve the measurement of gamma rays in conjunction with other reaction products. In all, a new generation of detectors needs to be developed.

Gammasphere, consisting of modules of Compton suppressed Ge detectors, has a total peak efficiency of about 0.1 (for 1 MeV gamma rays) and a peak-to-total ratio about 0.5. The low efficiency is due to the solid angle occupied by the Compton shields and due to gamma rays escaping the Ge detector. To improve this efficiency, the ultimate gamma-ray spectrometer could consist of a shell of hyper-pure germanium. Such a shell can overcome efficiency limitation by adding back the escaped energy captured in neighboring detectors and thus recovering the full energy. But, for high multiplicity events, the summing of two gamma rays hitting neighboring detectors causes a reduction of efficiency and an increase in the background. In order to reduce this summing, a prohibitively large number of detectors are required.

The new concept of GRETA is to use highly segmented Ge detectors such that all the interactions of every gamma ray could be resolved. Tracking would then identify each interaction belonging to a particular gamma ray. Tracking determines the sequence of the gamma ray interactions from the energy and position of each interaction with the help of the energy-angle relation of Compton scattering and the characteristics of pair production. The gamma-ray energy is obtained by summing only the interactions belonging to a single gamma ray and the problem of summing two gamma rays is avoided. Such an array could be built with 100-200 elements, and its geometry will be determined by a set of conditions defined by counting rates, gamma-ray energy, multiplicity and source velocity. GRETA would provide higher efficiency (0.6 for one gamma ray at 1 MeV and 0.1 at 15 MeV), improved peak-to-total ratio (>0.6), better position resolution (1 mm vs. 2-3 cm), higher counting rate, improved linear polarization capabilities and the possibility of background rejection. In the following we will give a short summary of the physics impact of the new capabilities of GRETA.

• Higher efficiency and peak-to-total ratio

The efficiency gain is important for studies with low cross sections (e.g. in actinide nuclei) and/or low beam intensities. Especially, it will benefit experiments at RIA where the intensity of the most exotic beams will be very low. GRETA would extend the high spin study of neutron-rich nuclei by about 4 neutron numbers. For high spin studies, where one has long cascades with high gamma-ray multiplicity, GRETA would provide a 1000 fold gain in the "resolving power" for isolating rare cascades such as those from hyper

deformed states. In giant resonance experiments, the combination of high efficiency and good energy resolution for high-energy gamma rays will be unprecedented.

- **Improved position resolution**

The localization of the first interaction point in a detector allows the determination of the gamma-ray emission angle and enables the correction of the Doppler shift of gamma rays emitted from fast moving nuclei. Through tracking, GRETA gives a position resolution of about 1 mm for the gamma-ray interaction points or, at a distance from the source of 15 cm, an angular resolution of 0.4 degrees. This angular resolution is more than one order of magnitude better than that of Gammasphere and it will provide a much better Doppler correction for gamma rays emitted from fast moving nuclei. As an example, neutron-rich nuclei produced by fragmentation reactions with the RIA beams ($E/A = 400$ MeV) will have recoil velocities of $v/c=70\%$. For a 1 MeV gamma ray emitted at 90 degrees to the recoil direction, the Doppler broadening would be 90 keV with a Gammasphere detector, but only 4 keV with GRETA.

- **Higher counting rate**

The segmentation and advanced digital signal processing will give GRETA a counting rate capability about 10 times higher than current arrays. This will provide enhanced statistical accuracy for all experiments, but will be especially important for the exploration of much rarer events. This ability is also important for resolving events which are closely correlated in time.

- **Linear polarization and background reduction**

Tracking provides additional benefits. One of them is the measurement of linear polarization, which is crucial in determining the parity of levels. Current Compton polarimeters based on unsegmented detectors have low efficiency due to multiple scattering and absorption in the crystal used as a scatterer. GRETA gives an accurate measurement of the azimuthal angle between the first and second interaction points and a higher efficiency in detecting the gamma rays, resulting in a large improvement in linear polarization measurements. Tracking will also allow the rejection of gamma rays not emitted from the target position and thus reduce background events. For example, in radioactive beam experiments, tracking could reject decay gamma rays from scattered beam particles on the wall of the target chamber. In low cross-section reactions, such as capture reactions for nuclear astrophysics experiments, it will reject background originating from outside the detector array.

In the next section, a more detailed physics case will be presented, together with the importance of GRETA to each of the physics areas. Chapter III gives a brief description of the concept behind GRETA and the status of its development. To construct the GRETA array, a new generation of detectors, signal-processing electronics, data acquisition systems and analysis tools needs to be developed. We will show the achievements of the R&D efforts in all the key areas of technology and demonstrate the proof-of-principle for GRETA.

II) PHYSICS CASE

The principal physics area benefited by GRETA is envisioned to be nuclear structure, and most of this section discusses this physics, beginning with high-spin studies. However, there are important applications in astrophysics and fundamental interaction physics which will also be discussed.

1. High Spin Physics

Some important questions in the study of nuclear structure at high angular momentum are: a) what is the maximum angular momentum a nucleus can sustain and what exotic shapes can be stabilized, especially near this limit; b) how is the shell structure changed - where are the new closed shells and which new high-j orbitals appear; and c) how is the rotational behavior affected by the quenching of pairing and the termination of some bands. Angular momentum is one of a few good quantum numbers of nuclear levels, and the forces associated with increasing rotational frequencies can change nuclear structure in a profound way. They lower the energy of an orbital with high intrinsic angular momentum, and often produce exotic shapes not observable at low spin. Superdeformed shapes with an axis ratio of 2:1 are such a case in which the combination of high-j orbitals, high rotational frequency and shell gaps produce a unique opportunity for studying rotation, single particle levels and pairing correlations. It is predicted that hyperdeformed states with a 3:1 axis ratio could exist at even higher spin. These states will involve extremely exotic orbitals, from 3 major shells above and below the spherical Fermi surface, which could produce new phenomena such as large stable octupole deformations. For these gamma-ray spectroscopy experiments, which use high coincidence fold to select weakly populated long cascades, GRETA will provide a 1000-fold gain in resolving power over an array such as Gammasphere.

Another exotic shape change, which was first studied in fast rotating astronomical objects, is the Jacobi shape transition from oblate to triaxial shapes. Recent data from the 8π spectrometer and from Gammasphere provide a tantalizing first hint for such a shape change. The observation of a Jacobi shape transition would shed new light on the physics of rotating finite quantum-fluids and the structure of nuclei at the extremes of angular momentum, as well as providing an intriguing connection between some of the largest and smallest rotating objects in the universe.

2. Nuclear Structure at the Proton Dripline

Research with heavy ions along the proton dripline has left two lasting legacies; vastly improved experimental techniques, and the sophistication of greatly evolved nuclear structure theories. Driven by new data on shapes, decays and binding energies from across the proton rich landscape, a wide variety of theoretical methods have been developed, including mean field calculations of shapes and binding energies (in traditional and relativistic frameworks), Hartree-Fock approaches and Monte-Carlo and other truncated shell models. These models have helped interpret the structure of proton rich nuclei, and have become powerful predictive tools.

There are questions, which still have to be answered along the proton dripline. In lighter nuclei the symmetry of $N=Z$ nuclei is particularly interesting. Comparing "mirror pairs" of nuclei has proved to be an exquisitely sensitive tool for probing wavefunctions and testing nuclear structure theories. When the $N=Z$ line approaches the dripline, mirror pairs may provide evidence for extended proton wavefunctions arising from their low binding energies. The role of pairing modes involving neutron-proton pairs, especially coupled to $T=0$ has yet to be understood, as has the question of whether $T=0$ and $T=1$ pairs coexist. The nuclei along $N=Z$ have unusually large binding energies, the "Wigner" energy, arising from cluster configurations. However, a detailed understanding of this extra binding, the nature of the clustering, and its structural manifestations remain to be understood. In heavier nuclei, the competition between particle and

electromagnetic decay is still to be fully investigated, as it is extremely sensitive to nuclear structure, so should lead to an improved understanding of the proton dripline and its nuclei.

For contemporary nuclear structure studies along the proton dripline Gammasphere triggered by the Argonne Fragment Mass Analyzer (FMA) or by the Washington University "Microball" has proven very powerful. However, for continued progress in understanding structure at the driplines, a more sensitive gamma-ray detector is needed. The new detector needs to be more efficient, granular and capable of faster data acquisition rates. With the "tracking" capabilities, which now appear feasible, ultra-sensitive gamma-ray studies using traditional heavy-ion fusion, fast-fragmentation beams, or near-barrier ISOL beams will be possible. A new detector will take us into detailed gamma ray spectroscopy in the nanobarn region for stable beams, (isolate cascades of 10^{-9} intensity) which is two orders of magnitude below what is possible now. For accelerated rare isotopes, precision measurements should be possible with beams with intensity below 10^3 particles per second. This will open up all the proton dripline for study.

3. Nuclear Structure at the Neutron Dripline

Adding a large number of neutrons, perhaps 50 or more, to a medium mass nucleus must have a profound influence on nuclear structure. Either the new neutrons mix homogeneously with the protons, pulling them out to larger radii and changing the topology of the mean-field potential, or they leave a "normal" core and wrap around the nucleus in a skin. In either case, the nuclear environment must be drastically modified, especially in the surface region, and surface-peaked interactions like spin-orbit and pairing forces must change. In turn, changing the potential shape and effective interactions will dramatically change the "magic" shell gaps and the quantum states expected at the Fermi surface which drive shape polarization, minimize binding energy and control collective modes. How these effective interactions change with neutron-to-proton ratio, especially for very neutron rich nuclei, is still a matter of educated speculation. Thus, further development of theories, which encompass all nuclei, need data from the very neutron rich side of the nuclear landscape.

Study of this evolution from the line of stability to the neutron drip line is a topic of intense current interest. These exotic nuclei are produced from fragmentation reactions, as well as transfer and secondary fragmentation reactions. Recent experiments at MSU and other laboratories have shown that it is possible to measure the excitation energy of the first excited state and the $B(E2)$ value from the ground state to the first excited state. In addition, states with spin up to 12 have been observed from prompt gamma rays emitted in fragmentation reactions. However, due to the large velocity of the fragments and the low position resolution of the detectors, the Doppler shift can not be fully corrected. Thus, the energy resolution is not sufficient to resolve complex spectra of odd and odd-odd nuclei as well as spectra with high gamma-ray multiplicity. GRETA will provide a position resolution of about 1 mm, which is more than one order of magnitude better than current detectors. For example, the Doppler broadening of a 1 MeV gamma ray, emitted perpendicular to the recoil direction from a nucleus with a velocity of $v/c=0.7$, will be 4 keV. GRETA is essential for these studies, which will be carried out first at current generation of fragmentation facility and later at RIA which will allow us to range far towards the neutron dripline.

4. Structure of Heavy Elements

The Coulomb force sets an upper bound on the charge that a nucleus can retain, and nuclei with more than 104 protons would fission instantly if it were not for the stabilizing effects of shell structure. The theoretical predictions of the location of the "Island of stability" are very sensitive to the strength of the spin-orbital force and to the diffuseness of the nuclear potential. The interesting questions are: a) what binds the heaviest nuclei; b) where are the shell gaps, both spherical and deformed; c) are higher order deformations important; and d) how does the fusion process work for the formation of super heavy elements. Various models have to be tested against experimental results on the nuclear structure of the heaviest possible nuclei

in order to gain confidence in their predictions of the properties of superheavy elements. Important observables are lifetimes, decay modes, deformations, Nilsson bandheads, alpha fine structures, and fusion cross sections. Also, the only evidence of hyperdeformation is from proton spectra of (d,p) reactions observed in heavy nuclei ^{234}U . As we discussed in the last section, it will be very interesting to study the high-spin states of these SD and HD states, since they involve exotic single-particle levels with the highest angular momentum. By observing gamma rays, we also can study the gamma decay back of the HD states to SD and normal deformed states, probing the inner barrier. The challenge of these experiments is the extremely low production cross sections and a large fission background. They require a gamma ray array with the highest possible efficiency and high rate capability coupled with a recoil separator and associated particle detectors.

5. Collective Modes of Motion in Nuclear Structure

Collective rotations, vibrations and pairing correlations are dominant and ubiquitous features of nuclear structure in the yrast domain. Heavy-ion induced Coulomb excitation and transfer reactions are the pre-eminent probes of such collective modes of motion for the nuclear many-body system. The high efficiency, resolving power, and precise Doppler correction capability provided by GRETA will enormously enhance exploitation of these powerful techniques, especially for study of interesting transfer channels and non-yrast bands that typically are populated at about 1% of the strength of the ground band with transition energies similar to those in the ground band.

Recently, Gammasphere coupled to particle detector arrays, such as CHICO, has been highly successful in studies of the evolution of collective rotational bands with angular momentum to spins as high as 40 in actinide nuclei. This is being exploited to study collective shapes and moments of inertia in rotational bands and the gradual evolution of K admixtures with increasing spin for rotational bands built on high-K isomeric states. In addition, components of double-octupole phonon states have been identified in ^{208}Pb and ^{96}Zr . There are many open questions that could be studied using GRETA, such as precise measurements of the evolution of collectivity and symmetries with angular momentum and temperature, or locating the strength distribution of multiphonon modes. Heavy-ion induced pair transfer has been used successfully to probe the quenching of pair correlations with increasing spin. GRETA would greatly enhance the ability to study pairing correlations and searches for diabolic pair transfer or nuclear analogs of the Josephson effect. GRETA would play a key role in studying the intriguing neutron pairing effects that should be manifest by the weakly-bound neutrons in highly neutron-rich nuclei that should become open to study using RIA.

6. Nuclear Properties at High Temperature - Chaos and Giant Resonances

The nucleus is an excellent laboratory to study chaotic phenomena. At low excitation energies there exist intrinsic quantum numbers that can be used to characterize nuclear configurations. At high excitation energies, because of a very large level density and level mixing, the concept of quantum numbers breaks down. The loss of quantum numbers (and their associated symmetries) is a signature of the onset of chaotic behavior. Important questions concerning chaos in nuclei are: a) where and how does chaotic behavior begin; b) how is the rotational motion damped and is there motional narrowing; and c) are there any remaining quantum numbers which enable some ordered states to survive. A variety of experimental quantities are used to investigate this phenomenon including level spacing, band interactions, rotational damping and spectrum fluctuations. The ability of GRETA to provide high-fold gamma-ray coincidence data for resolving levels in the region of high level density, and for selection of particular decay pathways, is essential for these studies.

Giant resonances provide a unique opportunity for the study of the high temperature behavior of nuclear shapes and shape fluctuations. The ability of GRETA to detect both low-energy and high-energy gamma rays, with high efficiency (10% at 15 MeV) and good energy resolution, is ideal for the next generation of

experiments on gamma decay of giant resonances. These include the study of giant resonances built on exotic shapes such as superdeformed and triaxial shapes, and the different decay pathways of dipole and quadrupole resonances. Most interestingly, weakly bound neutron-rich nuclei, produced with RIA beams, will have entirely new types of resonances due to the separation of neutron and proton density distributions (such as the “pygmy” resonance). These low-lying resonances will have fine structures, and GRETA's high efficiency and high energy resolution are essential for the studies of these new excitation modes.

7. Astrophysics

The synthesis of nuclei occurs in stellar environments and models of these processes depend on parameters from nuclear physics, such as mass, lifetime, decay mode, level structure, and reaction cross section. Nuclear astrophysics data are often difficult to obtain, since many important nuclei are far-from-stability, and the cross sections are very small because the relevant energies for the reactions are in the sub-barrier region. With its high efficiency, high rate capability, and ability to reject background, GRETA will greatly extend these measurements to lower yield and lower cross sections.

8. Fundamental Interactions and Rare Processes

The search for physics beyond the Standard Model is the major focus in the study of fundamental interactions. Experiments, which involve testing the conserved-vector-current hypotheses in weak interactions, use high precision measurements of beta-gamma angular correlations. Higher-order effects in quantum electrodynamics have been studied in multi photon decay of singlet and triplet positronium. These experiments require high precision and large counting statistics. Thus, GRETA with its higher efficiency, higher degree of segmentation, and better background rejection, would provide a capability for more stringent tests of the Standard Model.

III) TECHNICAL FEASIBILITY

Gamma ray energy tracking is a new concept, which uses highly segmented Ge detector elements to form a shell enclosing the source of the gamma rays. The position and energy of each of the interaction points of each gamma ray in the shell is determined from the pulse shape of the signals from the segments. Using these positions and energies, and the characteristics of Compton scattering and pair production, the interaction points belonging to a particular gamma ray are identified. The full gamma-ray energy is obtained by summing only the interactions belonging to that gamma ray and this avoids the problem of false summing of two gamma rays in a shell of unsegmented detectors. A tracking detector array could be constructed from 100-200 highly segmented Ge detectors with a cost comparable to that of Gammasphere.

In the last four years, the technology needed to realize the gamma-ray energy tracking array has been identified and developed. The "proof-of-principle" has been demonstrated in all the key areas. These are: 1) manufacture of segmented detectors which can provide signals required for resolving and locating individual interaction points; 2) electronics and signal processing methods for determining energy, time and position based on pulse shape digitization and digital processing of signals; and 3) tracking algorithms, using the energy and position information, to identify interaction points belonging to a particular gamma ray.

1. Segmented Detectors

The key element of GRETA is a Ge detector, which can give energy, time and three-dimensional position information of the gamma-ray interaction points. This can be achieved by segmenting one of the electrodes in two dimensions to provide two of the coordinates while the third coordinate can be derived from the drift time of the charges. There are many possible segmentation and packing schemes. One possibility is spherical packing, as is used in Gammasphere, using tapered hexagonal and pentagonal shaped detectors with a segmented outside surface.

A prototype detector of this type has been designed, produced, and extensively tested. This detector has a tapered hexagonal shape with six longitudinal and five transverse segmentations, which divide the outer surface into 36 segments. Signals from each of the segments, as well as from the center electrode, are read out. A new preamplifier was designed to satisfy the requirements of small size, low power consumption, fast rise time and a frequency-independent input impedance. This detector has an average energy resolution of 1.14 keV and 1.94 keV at a gamma-ray energy of 60 keV and 1332 keV, respectively. A total integrated noise of about 4 keV was measured up to a frequency of 40 MHz. This low noise is very important for an accurate pulse shape measurement and for a low trigger threshold.

2. Pulse-shape Analysis

To determine the interaction position in three dimensions a detailed understanding of the pulse shape is necessary. A signal is produced when electrons and holes, formed by the slowing down of the photo- or Compton-electrons, induce charges on the electrodes. As the charge drifts toward an electrode, the amount of the image charge changes and it causes current to flow in or out of the electrodes. The integral of the current on the segment where the charges reach provides the energy measurement. The duration of the current signal (drift time) is used to determine the drift distance, which give one of the coordinates of the interaction. The signals from the neighboring electrodes have a bipolar shape with a zero net charge. Their shape is sensitive to the path of the charges and they provide a position determination, in the other two coordinates, which is better than the size of the electrodes.

We have developed algorithms to analyze the digitized signal to obtain the position of the interaction points and we have carried out extensive position resolution measurements on the prototype detector. The measurements used a collimated gamma-ray beam to illuminate the detector and the Compton scattered gamma rays were detected in a collimated NaI detector. This set up allows us to define the location of the interaction point and the energy deposited in the Ge detector (a 662 keV gamma ray from the ^{137}Cs source deposits 374 keV in the Ge when undergoing a 90 degree Compton scattering). In the measurement, the signals from each of the segments were digitized with a waveform digitizer and were processed digitally. The digitizers have a sampling rate of 100 MHz and a resolution of 12 bits. By decomposing the measured signals in terms of a complete set of calculated signals, the position of the interaction points was determined. By comparing with the position distribution expected from the collimation system, we obtained a position resolution of 0.5 mm to 0.9 mm in all three dimensions. These results are much better than expected 'a priori' and they more than fulfill the requirements for efficient tracking.

The three-dimensional position resolution is an essential condition for gamma-ray tracking, but another requirement is the ability to resolve the locations and energies of multiple interactions in multiple segments. For example, a 1.3 MeV gamma ray interacts on average 4 times before it deposits all of its energy. Given the segment size of the prototype detector, it will produce on the average two interactions in two segments. To decompose these composite signals, we have explored three approaches; an adaptive grid method, a matrix inversion method based on single value decomposition (SVD), and a wavelet transformation method. The adaptive grid method provides a position resolution of 1-2 mm but it is slow. The SVD and the wavelet

methods give a resolution of about 4 mm, but they are faster. A combined technique such as using the SVD method as the first step and follow by the adaptive grid method seems to be a practical approach.

3. Tracking Algorithms

The goal of tracking is to take the energy and the position of the interaction points and identify the interaction points belonging to a particular gamma ray. Algorithms for tracking Compton-scattering and pair-production events have been developed. These algorithms are able to identify interaction points belonging to a given gamma ray, resolve multiple coincident gamma rays, identify gamma rays which deposit only partial energy in the detector, and determine the first and second interactions for Compton events. The current algorithm for Compton-tracking consists of three steps; cluster identification, evaluation of each cluster using the angle-energy relation of the Compton scattering to identify full energy events, and in the third step, recovery of failed events by splitting or combining clusters. The algorithm was developed using simulated events and tested with a number of different conditions such as the multiplicity and energies of the gamma rays as well as for various position resolutions of the detector. For a position resolution of 1mm, which is feasible from the prototype test, an efficiency of 33% and a peak-to-total ratio of 72% have been achieved for events with 25 gamma rays each with an energy of 1.33 MeV. This has to be compared with Gammasphere, which has an efficiency of 8% and a peak-to-total ratio of 50% under the same conditions. This will give a 1000 fold increase in resolving power for high spin studies.

In the pair production process, a high-energy gamma ray deposits most of its energy (Eg-1.022 MeV) at the first interaction point. The subsequent annihilation of the positron produce two 0.511 MeV gamma rays and each of them creates a cluster of interaction points. A tracking algorithm has been developed utilizing these characteristics. The tracking efficiency of a 10 MeV gamma ray in an event with twenty 1 MeV gamma rays is about 36% for a position of 1 mm. The efficiency of this algorithm can be improved by relaxing the requirement for both 0.511 MeV gamma rays to deposit their full energy. This will allow the recovery of partial escape events.

IV) CONCLUSION

The time is right to aggressively pursue the next step of development and implementation of the gamma ray energy tracking array. Currently, there is a strong need for this powerful array due to a broad range of physics opportunities with potential of new discoveries. Within a decade, RIA will provide completely new possibilities in the studies of nuclear structure, nuclear astrophysics and fundamental symmetries. GRETA is the only detector which can satisfy the requirements of experiments using low energy stable beams, low energy radioactive beams from ISOL method and high-energy radioactive beams from fragmentation. The feasibility of GRETA has been demonstrated through recent development work in the following key areas; segmented detector performance, position determination, signal decomposition, and gamma-ray interaction tracking. The construction of GRETA will maintain the US leadership in gamma-ray spectroscopy and ensure the long-term success of the low energy nuclear physics program.